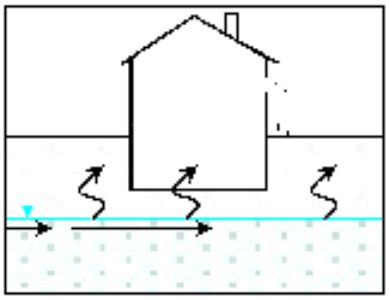

Addressing Vapor Intrusion at Remediation & Redevelopment Sites in Wisconsin

PUB-RR-800 December 2010

TABLE OF CONTENTS

Wisconsin Department of Natural Resources
P.O. Box 7921, Madison, WI 53707

I. Purpose and Applicability

The purpose of this program guidance is to identify the conditions where assessment of the vapor intrusion pathway at contaminated sites is necessary, set out the criteria for determining health risk at vapor migration sites, identify appropriate responses to vapor intrusion and delineate when sites with a complete or potential vapor migration pathway may achieve closure. Several vapor migration scenarios are provided as examples. Anyone applying this guidance to a contaminated site must also comply with the Chapter NR 700 rule series, including assessment and remediation of all pathways of concern.

This procedural guidance is applicable to all contaminated sites where volatilization of subsurface contaminants has the potential to migrate to current or future occupied buildings. Readers are referred to U.S. EPA[1], ITRC[2], and similar documents for guidance on methods of sample collection, calculation of exposure risk, laboratory methodology, and similar topics. Unless otherwise noted, all provisions in this guidance apply to the responsible party and/or property owner of a contaminated site. The process outlined in this guidance for assessing and investigating the vapor intrusion pathway applies, as appropriate, to undeveloped properties (where no buildings are currently present) as well as developed properties.

II. Overview of the Vapor Intrusion Pathway

The term "vapor intrusion pathway" generally refers to subsurface contamination that can move through the air-filled pores of vadose zone soils and enter the breathing space of buildings. Vapor intrusion can also occur when contaminated groundwater infiltrates buildings and contaminants directly volatilize from the groundwater into indoor air of the building. The "pathway" for vapor movement may be through permeable soils, through fractures in bedrock or clay tills, through man-made subsurface structures such as utility lines, through basement sumps, cracks in the building foundation, or through other mechanisms.

The potential for the vapor intrusion pathway should be assessed at all sites contaminated with organic and inorganic volatile chemicals. The volatility of the contaminant(s), potential for degradation and/or sorption in the vadose zone, and contaminant concentration should be considered during the initial site assessment in order to determine whether the potential for a vapor intrusion pathway exists. Other considerations include subsurface stratigraphy, soil moisture, depth to groundwater, distance of a building from the contaminant source, the building structure, competence of the foundation, presence of utilities and preferential flow paths, etc. If it is determined that there is potential for vapor intrusion into occupied or proposed building locations, NR 716.05(1) requires the vapor migration pathway be investigated as part of site investigation activities.

The details for this assessment are beyond the scope of this document. The reader is referred to ITRC's "Vapor Intrusion Pathway: A Practical Guide"[2] for information on the screening and site

[1] U.S. EPA guidance on Vapor Intrusion - http://www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm
[2] Interstate Technology Regulatory Council, Vapor Intrusion Pathway: A Practical Guide, January 2007. http://www.itrcweb.org/Documents/VI-1.pdf

investigation process for the vapor migration pathway. It is important to note, when preparing a vapor intrusion assessment, that in most cases the Department requires the use of empirical data representing the pathway of exposure. In general, the Department does not accept the use of models (such as the Johnson & Ettinger Model for Subsurface Vapor Intrusion into Buildings) for screening out the vapor intrusion pathway.

Due to their high volatility and health risk, volatile organic chemicals – particularly chlorinated volatile organic chemicals (CVOC) and petroleum – are the contaminants that most commonly trigger assessment of the vapor intrusion pathway. Depending upon site conditions, semi-volatile contaminants (such as PAHs, dioxins, PCBs, etc.) and mercury (a volatile metal) may also present a risk of vapor intrusion. This guidance does not address semi-volatile organic or volatile metal contamination. If vapor intrusion from these contaminants is suspected at a property, specific screening and investigation methods should be discussed with the DNR Project Manager.

Where a risk to human health exists due to the vapor intrusion pathway, mitigation of the vapor pathway will usually be necessary to protect building occupants. In addition, remediation of the vapor source will be necessary to minimize long-term risks.

III. **Background Indoor Air VOCs**

Modifications to assessment and investigation of the vapor intrusion pathway will likely be needed for situations that contribute VOCs to indoor air but where the indoor air VOCs may not have originated from the hazardous substance release.

- *OSHA Regulated Settings.* When the contaminant of concern is also a chemical used in a manufacturing or commercial process, OSHA (Occupational Safety and Health Administration) standards[3] or other occupational inhalation exposure guidelines apply to the indoor occupational exposure as long as the entity continues to use the chemical in question. When the building use changes and occupational standards and guidelines no longer apply, then the applicable indoor air health risk levels are determined by current land use. When investigating the vapor intrusion pathway, indoor air is usually <u>not</u> analyzed at OSHA regulated facilities.

  When a release to the environment has occurred, both OSHA and non-OSHA regulated facilities are expected to comply with the Chapter NR 700 rule series for environmental cleanup. Investigation of sub-slab vapors, soil vapors, etc. to identify the risk of vapor intrusion, as discussed in this guidance, are applicable to these facilities. Section VI of this guidance discusses the appropriate sub-surface screening levels that apply to commercial and industrial facilities.

- *Typical Indoor Air Concentrations.* Volatile organic chemicals routinely exist in indoor air due to outdoor air quality or to the presence of routine items such as recently dry

[3] This guidance does not address OSHA requirements. Those subject to OSHA are responsible for compliance to those rules.

cleaned clothes, oil based paints, spray can propellants, etc. in the building. For the purpose of assessment, the types and levels of these typical indoor air VOCs are considered to be "background" VOCs. Adjacent industrial or commercial facilities may also release certain VOCs to outdoor air, which may affect indoor concentrations of these VOCs. Where possible, background sources should be identified and preferably eliminated (usually by removing materials that contain VOCs from the building) prior to indoor air sampling. Vapor intrusion as an exposure risk may be ruled out if indoor air contaminants are determined to be solely or primarily due to background sources in indoor or outdoor air.

- *VOCs not related to a hazardous substance discharge*. Measured concentrations of contaminants that are not the result of a hazardous substance discharge do not require further action by the RR Program. However, action may be required by other regulatory or health agencies. Indoor air affected by a hazardous substance discharge, regardless of whether the discharge took place inside or outside the building, does require assessment as discussed in this guidance.

IV. **Vapor Intrusion Pathway Screening**

Vapor intrusion "pathway screening" is used to determine whether or not the potential for vapor intrusion exists on or off a contaminated property. If screening indicates the possible existence of a vapor pathway, the next step is to conduct an appropriate site investigation of the pathway(s). In any event, the ch. NR 716 Site Investigation Report will document the steps that were taken at the site to screen for the vapor pathway and will specify why an investigation was or was not conducted for vapor intrusion. The site investigation report will include all investigative methods and results, as required by ch. NR 716.

Vapor intrusion problems most often arise from light end petroleum products (such as gasoline) and chlorinated VOCs. Properties contaminated with volatile organic chemicals *other than* petroleum or chlorinated VOCs should consult with the DNR Project Manager to confirm appropriate screening criteria. Screening criteria specified for petroleum vapors are applicable to aerobically degradable VOCs.

A. Screening for Petroleum Vapors

Vapor intrusion of benzene and other petroleum constituents occurs most often when free phase product (or LNAPL - light non-aqueous phase liquid) is located near building foundations, where petroleum contaminated groundwater has entered a building, or where contaminated groundwater is in contact with the building foundation. Preferential pathways between the source and a building (e.g. fractured bedrock, utility line backfills, openings or cracks in the building foundation, etc.) can play a major role in the movement and accumulation of petroleum vapors to indoor air.

The most toxic of the petroleum constituents, benzene, readily degrades in unsaturated, oxygenated soils. Vapor intrusion from petroleum contaminated sites tends to occur in proximity

to the source of the petroleum release and is often detected by smelling petroleum odor in the building. **High concentrations of petroleum vapors can create an explosion risk; therefore the detection of petroleum odors in a building should immediately trigger an investigation into the source of the odors and, if necessary, evacuation of the building. Appropriate immediate or interim action, per ch. NR 708, Wis. Adm. Code, should be taken to eliminate the vapors**.

Vapors from petroleum can cause eye and nasal passage irritation to building occupants, even when no chemicals are detected above a health risk level. If building occupants complain petroleum odors or of mucus membrane irritation, investigate to determine if the vapor complaints are related to a release of petroleum product to the environment. If complaints of irritation from vapors are related to a petroleum product release, the vapor intrusion pathway must be investigated. When screening the vapor pathway, occupants of buildings near a petroleum release that is likely to off-gas vapors into the building should be asked if they have detected petroleum odors in the building.

Where no petroleum odors are detected, vapor intrusion can be ruled out at most petroleum releases based on the presence of 5 feet (in the horizontal and vertical direction) of clean, unsaturated soil with an oxygen content ≥ 5% between the residual petroleum and the building[4, 5]. Investigation of the vapor intrusion pathway should be undertaken in situations where 5 feet of clean, aerated soils are not present or where any of the following conditions exist:

- Free-phase product that has the potential for off-gassing vapors[6] underlies a building or is within 30 feet, horizontally or vertically, of a building foundation.
- Petroleum contaminated soils with the potential for off-gassing vapors are within 5 feet or less of a building foundation.
- Benzene concentration in groundwater underlying a building is >1,000 ppb and there is less than 20 feet of unsaturated soil between the groundwater and the building foundation.
- Groundwater contaminated with petroleum product above Wisconsin's groundwater preventive action limit (PAL) is entering a building or in contact with the building's foundation, or is in water intercepted by the building's foundation drain system, including sumps.
- Petroleum vapors are present that may migrate from the petroleum source and move through preferential pathways (sewer lines, fractured bedrock, etc.) into a building.

If none of the bulleted criteria are present, the investigator can assume that the necessary 5-feet of clean, aerated soil are present and rule out the vapor intrusion pathway. If one or more of the bulleted criteria is present, the investigator may need to confirm through soil testing that a 5-foot

[4] Luo, H., et.al., Spacial Variability of Soil-Gas Concentrations near and beneath a Building Overlying Shallow Petroleum Hydrocarbon-Impacted Soils, Ground Water Monitoring & Remediation, v. 29, no. 1, pp. 81 – 91.
[5] Davis, Robin, Update on Recent Studies and Proposed Screening Criteria for the Vapor Intrusion Pathway, LUSTLine Bulletin 61, May 2009, pp. 11 – 14, http://www.neiwpcc.org/lustline/lustline_pdf/lustline_61.pdf.
[6] This includes light end distillates such as gasoline. Heavier end petroleum products (diesel, fuel oil) or heavily weathered light end distillates that no longer contain compounds that are detectable by TO-14a or TO-15 analysis are less likely to be a source of vapors.

clean, aerated soil zone exists horizontally and vertically beneath the building in order to rule out the vapor intrusion pathway. If the vapor intrusion pathway can not be ruled out through this screening process, investigation should proceed as outlined in this guidance.

B. Screening for Chlorinated Volatile Organic Chemical Vapors

Chlorinated volatile organic chemicals (CVOC) generally do not degrade in vadose zone soils and tend to migrate greater distances from the source of contamination than petroleum hydrocarbons. Vapor intrusion investigations should be undertaken at almost all CVOC sites because of the mobility and toxicity of CVOC combined with the fact that these chemicals can not be detected by their odor at concentrations that present a human health risk. Vapor intrusion is a common risk at buildings located on the CVOC source property. Chlorinated VOCs can migrate from the source of contamination through unsaturated soils and enter near-by buildings through cracks or other openings in foundations. Groundwater can carry CVOC over long distances, allowing the CVOC to volatilize off the surface of the water table, move through the vadose zone soils, and enter buildings. The presence of on-site or adjacent utilities, such as sewers, sumps, French drains, and other subsurface migration pathways should be assessed for on-site and off-site migration pathways. The absence of an on-site VI concern does not rule out an off-site migration concern for the VI pathway. Contaminated groundwater entering buildings may also lead to vapor intrusion as the CVOC volatilize directly into the indoor air.

The vapor intrusion pathway should be investigated at all source properties where a release of CVOC has occurred. The screening criteria listed here apply to developed properties as well as to undeveloped properties (where no buildings currently exist). In addition to CVOC source properties, the VI pathway should be investigated in the following situations, regardless of whether these conditions exist on or off the source property:

- Any buildings overlying a CVOC soil source.
- Any buildings within 100 feet[7] of a CVOC soil source.
- Any buildings overlying a CVOC groundwater plume located at the water table with groundwater concentrations above Wisconsin's groundwater enforcement standards (ES).
- CVOC contaminated groundwater above Wisconsin's groundwater preventive action limit (PAL) is entering a building or in contact with the building's foundation, or is in water intercepted by the building's foundation drain system, including sumps.
- CVOC vapors have the potential to enter preferential pathways (sewer lines, fractured bedrock, foundation cracks or openings, etc.) that connect contaminated areas to a building and migrate into that building.

C. Factors Affecting Screening Distances for Vapor Migration

The actual extent of vapors emanating from contaminated soil or groundwater is affected by factors such as soil type, soil moisture, water level variation, extent of the groundwater plume, presence of preferential pathways, contaminant concentration, age of release, etc. As stated

[7] See Lowell, P.S. and B. Eklund, VOC Emission Fluxes as a Function of Lateral Distance from the Source, Environmental Progress, Vol. 23, No. 1, April 2004.

above, understanding the role of preferential pathways (such as utility corridors)[8] between the source and a building are critical to assessing the movement and accumulation of contaminated vapors to indoor air. The distances listed in this document are intended to be guidelines – the actual distances assessed will rely on site specific conditions and the results of the site investigation. Actual vapor assessment distance from the contaminant source may be more or less than the distances listed here, based on the factors listed previously in this document.

V. Investigation of the Vapor Intrusion Pathway

If vapor intrusion pathway screening indicates the potential for vapor intrusion, a plan for site specific vapor sampling should be developed. The purpose of vapor sampling is to identify which on or off-site receptors may be at risk for vapor intrusion and to determine appropriate responses to the sampling results. This section only provides guidelines for proceeding with a vapor intrusion investigation. The investigative approach taken in any instance will always be site specific.

In addition to the investigative approaches discussed here, it is critical to assess the building(s) where vapor sampling takes place. The type and condition of the building foundation, the location and condition of utility and foundation penetrations, and any other condition that would allow vapors to migrate into the building should be noted. This information, along with other pertinent observations and preparation of the building for sampling (e.g., removal of materials that contain VOCs, etc.) should be documented when vapor samples results are submitted to the Department.

The vapor intrusion pathway can be preemptively mitigated at any time during the site investigation. Section VII of this document and Chapter 4 of the ITRC guidance on vapor intrusion discuss approaches to vapor mitigation.

A. Investigating Vapor Intrusion at Properties with Existing Structures

In most cases, investigation of vapor intrusion will begin with buildings nearest the contaminant source and move outward from the source based on initial investigation results, distance to nearby receptors, extent of impermeable surface, preferential pathways, etc. This may require extending the vapor investigation beyond the source property. Each vapor assessment is unique to the characteristics of the site, and as such, a well-reasoned conceptual site model is critical to properly assessing the pathway.

Usually, a step-wise approach to investigating the vapor pathway is undertaken that includes collecting evidence at each step to determine the likelihood of vapor migration to a receptor. Groundwater and soil matrix sample concentrations should be used to help direct the vapor investigation. The most common situations contributing to vapor intrusion are listed here, along with a basic approach to initial site investigation of vapor migration. If initial investigative

[8] See the Department's "Guidance for Documenting the Investigation of Utility Corridors", http://dnr.wi.gov/org/aw/rr/archives/pubs/RR649.pdf

results indicate a risk of vapor intrusion, then additional investigation and delineation will be necessary to assess risk from the VI pathway.

1. *The original contaminant release is located directly below or adjacent to a building*. In addition to the standard soil matrix and groundwater investigation efforts, sub-slab vapor samples should be collected from beneath the building foundation. Site-specific conditions such as location of nearby buildings, degree and extent of contaminant migration in groundwater, subsurface conditions, etc. will dictate the need for collecting vapor samples beyond the source building.

2. *Vapors migrating from contaminated soil to nearby buildings*. Soil vapor samples, collected at approximately the same depth as the contaminant source, can help identify the extent of sub-surface vapor movement and identify buildings at risk of vapor intrusion. An alternative to soil vapor sampling is to collect sub-slab vapor samples from nearby buildings deemed to be at risk for vapor intrusion. If vapor concentrations in soil gas exceed screening levels (see section VI), sub-slab vapor samples of adjacent buildings will be necessary.

3. *Vapors migrating from contaminants located at the groundwater table*. A soil vapor survey can be conducted to identify buildings at risk of vapors migrating from contaminated groundwater. Soil vapor samples should be collected near the water table to assess the risk of vapor migration to overlying buildings. Soil vapor concentrations that exceed screening levels (see section VI) must be followed up with sub-slab vapor sampling at buildings deemed to be at risk. Alternatively, sub-slab vapor samples can be collected at buildings overlying the plume instead of soil vapor samples.

4. *Vapors migrating through preferential pathways, such as utility lines.* Soil vapor samples collected along underground utility service lines may be the most helpful in identifying this pathway. Sub-slab vapor samples should be collected from buildings served by utility service lines contaminated with volatile chemical vapors. If it is known that discharges are already migrating or suspected to be migrating through a utility corridor, the nature and extent of those discharges must be determined during the site investigation.

5. *Contaminated groundwater entering a building.* Sump pumps are often used to control shallow groundwater movement into buildings with basements. In situations where shallow, contaminated groundwater intercepts a building, it may not be possible to collect soil vapor or sub-slab vapor samples. In this case, the building sump should then be sealed and allowed to equilibrate for some period of time. Vapor samples should then be collected from head space overlying the contaminated groundwater. In addition, water should be collected from the sump and analyzed.

B. Investigating Vapor Intrusion at Properties without Existing Structures

Wisconsin administrative code ch. NR 716 requires that the VI pathway be evaluated whether or not a building is present at a property. Properties with residual soil and/or groundwater contamination may pose a threat of vapor exposure if buildings are constructed in the future. The potential for future exposure can be assessed through methods such as soil gas, groundwater

samples, and flux chambers. However, these techniques can not assess the effect a building will have on the migration of vapors. The most cost-effective approach to address the potential for vapor migration at a property without a building is to incorporate vapor controls into the new building design, such as a vapor barrier with passive or active venting. Moisture barriers are not vapor barriers. Vapor barriers must be designed specifically for the building, perforations through the barrier must be sealed and a passive or active venting system must underlie the vapor barrier.

In many cases, the Department's conditions of closure will require that vapor control measures be included in the new building design. If the new building will be constructed at some point in the distant future, the property owner can conduct further evaluation of the VI pathway at that time to determine if building control measures are needed.[9]

C. Collecting Vapor Samples to Investigate the Vapor Intrusion Pathway

Sub-slab, soil gas, and indoor/outdoor air samples are commonly collected to directly measure vapor concentrations. This discussion presents the Department's general expectations regarding when these samples are collected and basic quality control procedures. The work plan for every vapor intrusion investigation should contain standard operating procedures and quality assurance data objectives to ensure adequate collection and analysis of vapor samples. Sub-slab, soil vapor and air data results reported to the Department must include a description of the quality control procedures used in the field and laboratory (NR 716.13 and 716.15). Consultants should instruct the laboratory to report vapor and air results in units of $\mu g/m^3$.

1. *Sub-slab sampling*. The purpose of sub-slab vapor samples is to characterize the degree and extent of contaminated vapor directly beneath a building foundation, regardless of whether the foundation is a basement or slab-on-grade; determine the likelihood of an exposure pathway due to vapor intrusion; and initially evaluate whether mitigation of the pathway is needed. The Department strongly prefers sub-slab vapor samples to groundwater or soil gas samples for determining the risk posed by vapor intrusion to occupants of a building. The results of the sub-slab sampling can be used to rule out the vapor pathway or to determine that additional investigation or action is necessary to address the vapor pathway (see Section VI below).

   Sub-slab sampling at commercial and industrial buildings should target the areas where contaminant releases are known to have (or may have) occurred. At buildings where a release has not occurred but where the vapor intrusion pathway is a concern (such as homes, nearby businesses, etc.), the Department recommends that 3 sub-slab samples be collected at buildings with a footprint less than 5,000 square feet. For larger buildings, an additional sub-slab sample should be collected for each additional 2,000 square feet. At large commercial/industrial facilities where this sampling density is unworkable, other approaches,

[9] See U.S. EPA's Brownfield Technology Primer for more information. http://www.brownfieldstsc.org/pdfs/BTSC%20Vapor%20Intrusion%20Considerations%20for%20Redevelopment%20EPA%20542-R-08-001.pdf

such as modified soil venting assessment techniques, can be effective in assessing the sub-slab vapor concentrations.[10]

In general, results from multiple sub-slab sampling points should NOT be averaged. Results from each sample should be evaluated individually. The information from a sampling network helps the investigator identify "hot spots" of contamination and preferential pathways for vapor movement. Large buildings are often subdivided into smaller spaces when they undergo redevelopment which may change air exchange patterns and may heighten a vapor intrusion problem. However, there are situations, such as in large industrial or commercial buildings, where area-weighted averaging of sub-slab vapor concentrations may be useful. In these cases, the contaminated areas beneath the building should be evaluated separately from the non-contaminated areas in order to evaluate vapor intrusion risk and, where necessary, properly target remedial action and vapor mitigation.

Sub-slab vapor samples can be collected in vacuum gas canisters fitted with a controller to limit vapor flow to no more than 200 ml/min (a 6 L canister will fill in approximately 30 minutes at this flow rate). Vapor samples should be analyzed using Method TO-15 or Method TO-14a for the chemicals of concern identified from soil and groundwater sampling conducted at the site. The use of other sampling equipment or laboratory methods should be discussed with the DNR Project Manager.

Quality control for sub-slab sampling should include a combination of vacuum testing of lines and leak detection tracers to ensure the integrity of the sample. Sample lines extending from the sub-slab probe to the Summa canister should be vacuum tested for tightness prior to sample collection and a leak tracer compound should be released around the sub-slab probe during sample collection. Several leak tracer compounds are available (such as pentane, isopropyl alcohol, helium, and SF6). The Department recommends the use of helium because it allows the detection and correction of leaks prior to sample collection.[11] If a leak tracer other than helium is used, the selection of the leak tracer compound should be coordinated with the analytical laboratory to ensure that its presence in sub-slab vapor samples will not interfere with the analysis of target compounds. If the leak tracer compound is detected at more than 10% leakage rate by volume in the sub-slab sample, then the sample results should be rejected. In this case, resample the sub-slab probes with improved sample collection techniques. (Note: to determine leakage rate, it is necessary to sample the concentration of leak tracer beneath the tracer shroud, which is placed over the sub-slab probe to contain the tracer gas.)

2. *Soil Gas Samples*. Soil gas samples are best used as a survey tool to identify buildings at risk of vapor intrusion where follow-up sub-slab vapor testing will be performed. Sub-slab samples are strongly preferred to other vapor samples in assessing vapor concentrations at specific buildings. In cases where sub-slab sampling is precluded or where contamination

[10] McAlary, T., et.al., High purge volume sampling – a new paradigm for subslab soil gas monitoring, Ground Water Monitoring & Remediation, v. 30, no. 2, Spring 2010, pp. 73 – 85.
[11] See the ReNews Article "Detecting air leaks when collecting sub-slab samples" at http://dnr.wi.gov/org/aw/rr/technical/subslab.pdf for more information.

exists over a wide area, the use of soil gas samples to assess vapor intrusion potential to indoor air should be discussed with the DNR Project Manager. Soil gas samples should be collected considering these guidelines:

- If the vapors originate from contaminants in groundwater (water table 30 feet or less below ground surface), soil gas samples should be collected 1 to 2 feet above the water table and as near the building being assessed as possible. If the water table is greater than 30 feet below ground surface, a soil gas sample should be collected half the distance to the water table.
- Where groundwater conditions permit, soil gas samples should be collected from a depth of at least 5 feet or more below the building foundation. Where no building exists, soil gas samples should be collected at least 5 feet below ground surface.
- Soil gas samples should be collected from zones of more permeable material because vapors can more readily move through transmissive zones to nearby receptors.
- If site conditions preclude the application of the above distances, alternative vapor sampling methods and approaches should be discussed with the DNR Project Manager.

Soil gas samples should be collected on the side of the building nearest the contaminant source. If contaminated groundwater is the source, soil gas samples should be collected on all sides of the building.

Soil gas samples may be collected using vacuum canisters or Tedlar bags, if laboratory analysis of the Tedlar bag occurs within 48 hours. Laboratory analysis should be conducted in the same manner as for sub-slab vapor samples. Soil gas samples should use the quality control procedures (vacuum testing of sample lines and leak tracer testing) described for sub-slab probes above.

3. *Utility Corridors as Preferential Pathways*. If subsurface utility corridors or geologic features provide preferential migration pathways for contaminant vapors, passive or active soil gas surveys may be the best tool for identifying the migration pathways and should be incorporated into the site investigation. Unique sampling schemes may be necessary when dealing with preferential pathways, for example, a combination of indoor air samples and vapor samples from sewer vents or along utility backfill may be needed. Other approaches may help focus locations for vapor migration investigation, such as video logging of storm or sanitary sewers in cases where chemicals may have entered sewer systems and migrated along utility lines.

4. *Indoor and outdoor air sampling*. The goal of indoor air sampling is to determine if there is a complete exposure pathway due to vapor intrusion and to determine whether mitigation or remediation is necessary to address unacceptable risks. Indoor air sampling is also necessary after a mitigation system is installed and operating. An outdoor (ambient) air sample should be collected whenever indoor air samples are collected. The outdoor sample provides information on the air quality surrounding the building. The outdoor sample should be collected using the same procedures as the indoor sample.

   Indoor air samples are often collected after results from sub-slab vapor sampling indicate screening levels are exceeded (see Section VI below). However, indoor air samples may be

collected concurrently with sub-slab vapor samples (but not during installation of sub-slab probes). An investigator cannot usually determine whether a vapor intrusion pathway exists with only indoor air sample results. The indoor air sample should be accompanied by corresponding (although not necessarily concurrent) sub-slab or sump samples. Here are some considerations for determining whether indoor air samples should be collected (these considerations assume that sub-slab vapor concentrations exceed screening levels).

- The presence of building occupants, particularly residents. Indoor air samples should always be collected in buildings where people are currently living or working in order to rule out an unacceptable exposure.
- The concurrent use of the contaminant(s) of concern. Indoor air samples should not be collected in a building space that currently uses the contaminant of concern. For instance, indoor air samples should not be collected for perchloroethylene (PCE) at a dry cleaning facility that uses PCE in the dry cleaning machine or as a spot treatment.
- Abandoned or inactive building. If a building is unoccupied and the heating, ventilation, and air conditioning (HVAC) system is not operational, an indoor air sample is unlikely to be representative of normal building operations and may not be useful in determining the potential for exposure.
- Industrial facilities with a large footprint and various mechanical and/or chemical operations. It may be difficult to collect a representative indoor air sample due to the size and scope of large industrial facilities. The need for indoor air sampling under these conditions should be discussed with the Department PM.

Prior to indoor air sampling, conduct a survey for any items that may contribute VOCs to the indoor air and remove those items from the building at least 24 hours prior to sampling. Indoor air samples should be collected as 24-hour (residential) or 8-hour (commercial/industrial) time-weighted samples using vacuum gas canisters. Indoor air should be sampled on the lowest occupied level of the building and in commonly occupied spaces with the sampling canister placed approximately 3 to 5 feet above the floor and near the center of the room, away from windows. One indoor air sample from each level of a typical residential home should be adequate while multiple samples will likely be necessary from commercial facilities (especially those with individual business spaces) and industrial facilities. Samples should be collected under normal operating conditions of the building (i.e., doors opening/closing, regular HVAC operations, etc.). In the summer months, windows should be closed at least 24 hours prior to sampling and during sampling to minimize contribution from outdoor air.

Laboratory analysis of indoor air samples should focus on the contaminants of concern and should achieve detection limits that are 10 times lower than the targeted indoor air Action Level. Summa canister samples and laboratory method TO-15 should be used for indoor air, although method TO-15 SIM may be necessary to achieve required detection levels for certain contaminants. The use of passive indoor air samplers that allow collection of 7 or 14 day samples with laboratory methods that meet the detection levels for target contaminants are acceptable for assessing indoor air contaminant risk.

If results from indoor air concentrations are believed to be due to “background” or typical indoor air VOC sources rather than vapor intrusion, further evaluation should be conducted

to try and determine the source of indoor air contaminants. Where possible, remove materials contributing the VOCs prior to any subsequent testing.

VI. Assessing the Risk Posed by the Vapor Intrusion Pathway

The major goals of investigating the vapor intrusion pathway are to identify the vapor source and the pathway(s) of vapor movement into buildings (on- or off-site), to determine whether vapor migration is a risk to current or future users of the building and where necessary, to aid in designing and implementing remedial actions to interrupt or eliminate the exposure pathway. This section addresses the Vapor Action Levels (VAL) and vapor risk screening levels (referred to as screening levels throughout) that should be applied when assessing the health threat from vapor intrusion and how to apply these when assessing vapor data. Site investigation reports should clearly state the land use classification (e.g., residential, commercial or large industrial) used to determine VAL and screening levels appropriate to the site.

A. Vapor Action Levels and Vapor Risk Screening Levels

A Vapor Action Level (VAL) is equal to the lesser concentration of the following: a hazard index (HI) of 1.0 or a 1-in-100,000 (1×10^{-5}) excess lifetime cancer risk. Contaminant concentrations in the breathing space of buildings should be compared to the contaminant's VAL, taking into consideration exposure conditions (i.e., residential or commercial/industrial building use). Concentrations in indoor air equal to or exceeding the VAL require additional action and are to be addressed as part of the site remediation effort.[12]

1. *Applying Vapor Action Levels*. Vapor Action Levels for indoor air exposures are based, in part, upon standard U.S. EPA risk calculation methods. Tables and equations for indoor air concentrations can be found at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.[13]. The tables found at this web site provide screening levels for residential and industrial indoor air exposure scenarios. The screening levels for non-carcinogens correspond to a HI=1.0 while the screening levels for carcinogens correspond to a 1-in-1,000,000 excess lifetime cancer risk. Therefore, the screening values provided for carcinogens should be multiplied by 10 to determine the Wisconsin VAL.

   If multiple contaminants from a vapor intrusion source are present in indoor air, the total risk (the additive risk of each of the contaminants individually) can not exceed a HI of 1.0 or a cumulative risk of 1 additional cancer per 100,000 population (1-in-100,000 excess lifetime cancer risk).

   There are circumstances when immediate action is needed to halt inhalation exposures by occupants when a contaminant level in air reaches or exceeds a certain concentration. For non-carcinogens, this is when the concentration and appropriate exposure factors (dose,

[12] See DNR-DHS memo "Vapor Intrusion Action Levels and Screening Levels", attached.
[13] Soil inhalation pathway values are NOT an acceptable method to estimate screening values for the vapor intrusion pathway.

duration, frequency, etc) indicate the exposure may result in adverse health effects (symptoms or disease). For carcinogens, this is when the concentration and appropriate exposure factors (dose, duration, frequency, etc) estimates the excess lifetime increased cancer risk is at or exceeds 1-in-10,000. The Wisconsin Department of Health Services (DHS) and the local city or county health department should be contacted to assist with assessing such exposures. Under such circumstances DHS and the local health department may declare that the situation constitutes a "human health hazard" (s. 255.59, Wis. Stats.), which requires immediate action to halt such an exposure.

2. *Screening Levels for Residential and Small Commercial Buildings*. To determine screening levels for samples used to estimate indoor air concentrations, such as sub-slab vapor, soil gas or groundwater concentrations, use standard vapor attenuation factors contained in current U.S. EPA guidance. Attenuation factors[14] can be found at http://www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm. U.S. EPA may adjust these attenuation factors in the future. As of 2010, commonly applied vapor attenuation factors include:
   - 0.1 sub-slab vapor to indoor air
   - 0.1 shallow soil gas[15] to indoor air
   - 0.01 deep soil gas[16] to indoor air
   - 0.001 groundwater to indoor air (where vapor concentrations are calculated from partitioning across the water table using Henry's Law)

3. *Screening Levels for Large Commercial/Industrial Buildings.* U.S. EPA based their vapor attenuation factors primarily on observations at residential homes. Because large commercial/industrial facilities are different from residential homes in several areas that affect vapor intrusion, the vapor attenuation factors may be reduced by a factor of 1/10, if criteria listed below are met. In this case, the applicable attenuation factors at a large commercial/industrial facility may be:
   - 0.01 sub-slab vapor to indoor air
   - 0.01 shallow soil gas[15] to indoor air
   - 0.001 deep soil gas[16] to indoor air
   - 0.0001 groundwater to indoor air

   The following criteria should be documented in order to justify applying a reduced vapor attenuation factor at a large commercial/industrial building.
   - Building size. Commercial/industrial buildings typically have a significantly larger footprint than homes. The interior of the building should be open to air flow rather than subdivided into smaller offices or businesses.
   - Foundation thickness and structural integrity. Commercial/industrial buildings are often slab-on-grade construction with thicker and more intact concrete slabs than residences.
   - Ceiling height. Ceilings are usually considerably higher in commercial/industrial facilities, increasing the air volume compared to residences.

[14] Vapor attenuation factor (α) is defined by: $\alpha = \text{Concentration}_{(\text{indoor air})} \div \text{Concentration}_{(\text{source})}$
[15] Shallow soil gas samples are defined as those collected 5 feet or less below the building foundation.
[16] Deep soil gas samples are defined as those collected more than 5 feet below the building foundation.

- Air exchange rate. Higher ventilation rates in commercial/industrial buildings should result in lower indoor air concentrations, if the rate of vapor intrusion from the subsurface is constant.

B. Applying VAL and Screening Levels to Vapor Intrusion Risk

When assessing risk posed by the vapor intrusion pathway to a specific receptor, the Department prefers sub-slab samples over indoor air samples. Sub-slab vapor is more likely to originate from contaminant sources beneath or outside the building; can reveal the potential for vapor intrusion before contaminants have entered the breathing space; and contaminant concentrations may be less variable with time as compared to indoor air. In most cases, **negative indoor air samples alone are NOT adequate evidence to rule out the vapor intrusion pathway**; however, sub-slab sampling alone or in conjunction with indoor air sampling may be able to rule out the pathway.

After vapor samples are collected and contaminant concentrations are compared to VAL or screening levels, determine whether further action regarding the vapor pathway is necessary based on these decision criteria.

1. *Sub-slab concentration is less than screening levels.* Measured vapor concentrations in the sub-slab that are less than the applicable screening levels (considering the appropriate risk exposure and attenuation factor) indicate there is not a risk to human health due to vapor intrusion. In this scenario, the vapor intrusion pathway will be considered adequately addressed.

2. *Sub-slab concentration is greater than screening levels.* Sub-slab vapor concentrations equal to or greater than a screening level indicate the potential for vapor migration into a building and require further action to assess the vapor intrusion pathway and/or to reduce the on-going migration of contaminants.

3. *Indoor air concentration is equal to or greater than VAL due to migration from subsurface contaminants*. Indoor air equal to or greater than an Action Level requires that exposure of building occupants to the chemical vapors be reduced; that the extent of the vapor migration be determined; and that on-going migration of contaminants be remediated. The Wisconsin Department of Health Services should also be apprised of indoor air concentrations above VAL.

4. *Vapor concentration in other media exceeds the screening levels*. Assessment of soil gas and/or vapor migration of VOCs from the water table surface can be used to screen for the potential of vapor migration at redevelopment sites that currently lack buildings or at sites where vapor intrusion may be occurring over a wide area. Screening levels for vapor migration potential should be calculated as discussed above, considering the appropriate attenuation factors. If the soil gas concentrations exceed the screening levels, appropriate action should be taken, such as installation of a vapor barrier at new buildings or additional vapor assessment at nearby buildings.

5. *Soil gas concentrations in utility corridors/rights-of-way*. Soil gas sample results from utility corridors or in rights-of-way should be treated as deep soil gas samples, using an attenuation factor of 0.01. If contaminant concentrations exceed the screening values then additional investigation of the vapor pathway is warranted. Utility owners should be informed of the vapor concentrations identified in the utility corridor(s).

C. Role of Department of Health Services (DHS) in Evaluating Risk from Vapor Intrusion

Both the Department and DHS have responsibility for ensuring that human health is protected at contaminated sites. There are overlaps in responsibilities between the two agencies regarding indoor air risks at vapor intrusion sites. Department of Health Services focuses on the contaminated sites where a risk to human health is likely to exist and must follow-up on these risks with local health departments.

Consultants and responsible parties can seek help from DHS when investigating the VI pathway. Situations in which DHS staff either must be consulted or can provide additional support include:

- When indoor air concentrations exceed VAL of contaminants in an occupied structure. Remediation staff works in concert with DHS to ensure that the indoor air risk is mitigated and building occupants are protected.
- When help is needed to interpret indoor air results.
- When support is needed to gain access to homes or businesses to collect sub-slab or indoor air samples; to communicate risk from chemical exposures; to explain why samples need to be collected; or to address health concerns or questions.

VII. Responses to Vapor Intrusion that Exceed VAL or Screening Levels

When a vapor sample concentration exceeds a VAL or a vapor risk screening level, one can not automatically conclude that vapor intrusion is occurring. All lines of evidence should be evaluated to determine the likely source of the contamination, pathways for vapor movement and the effect on receptors. This may require revising the site investigation workplan and enlarging the site investigation. If, after assessing the lines of evidence, it is determined that vapor intrusion poses a threat to building occupants action is to be taken to address the source of the hazardous substance discharge in accordance with ss. 292.11(3), Wis. Stats. **In most cases this will require remediating, to the extent practical, the source of the contamination in order to address long-term risk and interrupting the vapor intrusion pathway to address near-term risk and protect receptors.**

A. Remediation and Mitigation

Remediation of the vapor source is the most effective way to confidently eliminate the long-term risks of vapor intrusion from sources such as contaminated soils, groundwater, and/or NAPL. For more information on the remedy selection process see NR 722, Standards for Selecting Remedial Action.

The Department expects that vapor mitigation will be implemented at buildings where sub-slab vapor concentrations exceed screening levels. Several options exist for interrupting the vapor intrusion pathway in order to protect human health[17]. Vapor mitigation technologies for buildings include:

- sealing potential vapor entry points
- sub-slab depressurization
- vapor barrier and passive venting for new construction
- building pressurization/HVAC modification at commercial and industrial facilities

The most common way to interrupt the vapor pathway in existing structures is to install a sub-slab depressurization system (SSDS; often referred to as a "radon system" for its similar use in mitigating radon gas at buildings). Sub-slab depressurization systems actively maintain a negative pressure gradient between the sub-slab and indoor air.

Sub-slab depressurization systems are not remediation systems and *should not* be considered as a remedial action that adequately addresses the source of the vapor intrusion pathway. **Source control (i.e., remedial or interim actions involving soil or groundwater treatment, excavation or a combination of these) will usually be the best approach to reduce or eliminate the vapor intrusion pathway.** Source control will also reduce the amount of time an SSDS must operate and will help ensure long-term protection of public heath. The goal of source control should be to reduce indoor air and sub-slab concentrations to levels below VAL and screening levels without on-going operation of a SSDS. The reasonable life expectancy of a SSDS fan is 10 to 15 years. Therefore, the goal for the source control remedy should be to reduce vapor concentrations in the subsurface to protective levels well within this period of time.

Passive sub-slab depressurization at a vapor intrusion site is typically acceptable only at new construction where a full vapor barrier is installed beneath the building slab in conjunction with the passive vapor extraction system. Even in these cases, the Department recommends that the passive depressurization system be designed so that it can be attached to a blower if subsequent testing indicates that active depressurization is needed.

B. Verification

A newly installed mitigation system must be tested to verify it is functioning as designed. Verification testing should be performed by the Responsible Party or the building owner. The Department will audit the performance of these systems on a periodic basis[18]. Verification testing should include:

1. *Pressure gradient.* Effective SSDS operation requires that a pressure gradient exist across the foundation slab such that pressure below the slab is lower than indoor air pressure. All SSDS should be instrumented with a pressure gauge or manometer to monitor pressure within the depressurization system. Manometer or pressure gauges should be recorded monthly to ensure the SSDS is operating properly. In addition, at large commercial or

[17] For more information on mitigation technologies, see the ITRC Practical Guide to Vapor Intrusion

[18] The Department may audit the on-going operation and maintenance of vapor mitigation systems both pre- and post-closure.

industrial buildings sub-slab pressure measurements should be confirmed with sub-slab pressure gauges or through smoke testing to ensure that negative pressure exists across the slab throughout the VOC contaminated area.

2. *Indoor air sampling*. Indoor air verification samples should be collected after a mitigation system has been installed and is operating to confirm that an exposure is not occurring. If VAL was exceeded prior to mitigation, indoor air samples will be required after installation of the mitigation system to demonstrate that the exposure no longer exists. The verification samples should confirm that indoor air concentrations are below VAL and that vapor intrusion does not present a health risk. Verification samples should be collected after the system has been operating a minimum of 3 months. If indoor air concentrations are above VAL after operation of the mitigation system, then the source and pathway should be reassessed and additional actions taken to reduce exposure risk.

C. Additional Monitoring

Additional monitoring of sub-slab and/or indoor air may be conducted in response to sample results that exceed screening levels and/or VAL. However, the following apply:

1. *Vapor Action Level exceeded by 10X*. If indoor air concentrations exceed a 1-in-10,000 lifetime cancer risk, immediate action pursuant to ch. NR 708, Wis. Adm. Code, must be taken to immediately stop the exposure, even if additional monitoring occurs. This may include removal of occupants from the building until risk levels decline to less than VAL.

2. *Vapor Action Level exceeded*. Immediate follow-up testing and assessment to interrupt the vapor pathway must occur at any location where contaminants of concern in sub-slab and indoor air exceed both screening and VAL.

3. *Vapor Action Level not exceeded*. Additional sampling of sub-slab and/or indoor air may be conducted to assess the vapor pathway when screening levels are exceeded but contaminants of concern in indoor air are less than VAL. A responsible party may propose an on-going, long-term monitoring program in an effort to rule out the exposure pathway to the indoor air in the future. Any on-going vapor monitoring program should include a sampling frequency and duration that takes into account land use, seasonality, building use, occupant exposure, and changes that may occur in the future to the building itself (such as aging of the building, remodeling that affects the vapor pathway, etc.). However, the cost of this approach could quickly exceed the installation and operation of a mitigation system.

VIII. **Closure at Sites with a Vapor Intrusion Pathway**

Sites with a potential (i.e., sub-slab screening levels exceeded) or complete (i.e., VAL and screening levels exceeded) vapor intrusion pathway can be considered for closure under NR 726 if all of the following circumstances are met:

- All other contaminant migration pathways on- and off-site have been addressed in accordance with NR 726.

- Remediation and mitigation of the vapor intrusion pathway results in contaminant levels less than VAL in indoor air. The Department will expect indoor air verification sampling when mitigation systems are operating.
- The contaminant source from which vapors are migrating has been remediated to the extent practical to reduce future vapor migration and to reduce to the extent practical the length of time a vapor mitigation system must be operated to protect the pathway.
- The property owner(s) and any affected occupant(s) of a building(s) with a vapor intrusion risk have been notified that they are responsible for maintaining the mitigation system as long as necessary to protect the vapor intrusion pathway. The closure letter will require that an operation and maintenance plan be on file with the Department and in the possession of the building occupant. An agreement may be entered into between the property owner and the Responsible Party regarding the responsibility for the future operation and maintenance of the mitigation system.
- The property where the hazardous substance release occurred, as well as the property where vapor intrusion is occurring (if different from the source property) must be entered onto the Remediation & Redevelopment Program's on-line database. Appropriate fees, in accordance with ch. NR 749, Wis. Adm. Code, must be paid to the Department.

In addition, the closure letter will include a requirement that any post-closure change in exposure conditions used to determine VAL be reported to the Department. The closure letter will require that the property owner/developer contact the Department prior to building or property use changes (e.g., from industrial/commercial to residential). The property owner/developer will be required to provide the Department with plans for building use changes and describe how the vapor pathway will be protected. Actions required of the property owner/developer may include reevaluation of the vapor intrusion pathway, additional source control measures and/or installation of more stringent vapor controls to ensure protection of people using the building.

IX. **Examples**

This section provides examples for applying the principals contained in this guidance to sites with vapor intrusion issues. In addition, these examples discuss conditions where additional investigation and remediation maybe necessary and when sites with VI can be considered for closure.

Example No. 1 – CVOC Contaminated Soil beneath a Building

A former dry cleaner operated in a strip mall for 20 years and a new tenant now occupies the space. Soil and groundwater impacts exist beneath several different commercial businesses in the strip mall. Groundwater monitoring indicates the plume meets the criteria for natural attenuation closure and the direct contact pathway due to soil contamination has been addressed. However, given the presence of tetrachloroethylene (PCE) contamination in soil and the water table wells, it was determined that the vapor intrusion pathway needed further evaluation. Sub-slab sampling revealed PCE vapor beneath the building.

- Scenario A – The measured concentrations in sub-slab vapor samples are less than the screening level for the given exposure conditions. The sub-slab vapor does not pose an

exposure risk and because the soil and groundwater pathways have been addressed, the site could be closed under NR 726. Closure conditions will include a requirement to notify the Department if land use changes and the exposure conditions present at the time of closure no longer apply.

- Scenario B – The measured concentrations in sub-slab samples are greater than the PCE screening level for the given exposure conditions. Indoor air samples were collected after receiving the sub-slab sample results and the indoor air levels are less than the applicable VAL. An evaluation of the sampling methodology and frequency confirm that adequate data were provided. While a current human health risk does not exist (based on PCE indoor air concentrations), the potential for a future health risk does exist (based on PCE in sub-slab vapors). Remedial action should be taken to reduce the source of contamination to the extent practical. Given the sub-slab concentrations, a sub-slab depressurization system or other mitigation system should be installed and operated in order to minimize worker and customer exposure to the contaminants in the future.

  Once the source has been remediated to the extent practical and the mitigation system is being operated for the purpose of minimizing exposure of building occupants to unacceptable vapor levels indoors, the requirements of NR 726 have been met and the site could be closed. The continued operation of the sub-slab depressurization system or other mitigation system will be included as a condition of the final closure letter so that the current and future property owners are aware that continuous operation of the system is necessary. The Department's closure letter will specify other conditions of closure. This site would be a candidate for future environmental audits by the Department to ensure the system remains operational.

  As an alternative to installing a mitigation system, a long-term vapor monitoring program could be proposed in order to assess the vapor pathway into the future in accordance with principles discussed earlier in this guidance (see Section VII, part C). As long as sub-slab vapor concentrations remain above screening levels and mitigation has not been implemented, closure is not possible. In accordance with NR 726.05(4), closure may not occur if at any time in the future the remaining level of contamination is likely to pose a threat to public health, safety, welfare or the environment.

- Scenario C – The concentration in sub-slab samples exceeds screening levels and indoor air concentrations exceed the VAL for PCE. This situation represents an unacceptable inhalation exposure and action to reduce or eliminate the exposure to contaminant vapors should be taken as soon as possible. Indoor air sampling will be required by the Department after the mitigation system is operating in order to establish that the mitigation system has reduced the inhalation risk to below VAL. In addition, the RP is expected to implement an appropriate remedial action at the site in order to reduce the mass at the contaminant source and thereby minimize the on-going vapor intrusion.

Example No. 2 – Redevelopment of a CVOC Contaminated Property

Trichloroethylene (TCE) is present in soil and shallow groundwater at a site that is being evaluated for redevelopment. The development plan[19] calls for a below grade parking lot, office space at grade level, and condominiums on the upper levels of the building. A large portion of the source area was removed and groundwater monitoring shows the plume is receding. The soil direct contact pathway will be addressed with the construction of the building and associated soil placement for landscaping purposes. The building is designed to vent car exhaust from the parking structure to the atmosphere so it doesn't migrate to the existing office space or condos.

- Scenario A – Soil gas and/or groundwater concentrations are less than applicable screening levels, indicating that TCE concentrations are likely to be less than VAL in residential areas. The operation of the parking structure exhaust system will ensure that the vapor intrusion pathway is protected. Because the other pathways of concern have also been addressed, the requirements of NR 726 have been met and the site can be closed.

- Scenario B – Sub-surface vapor testing reveals that concentrations beneath the proposed building may be greater than the TCE screening level for residential dwellings. A vapor barrier and passive venting system beneath the building, in addition to operation of the parking structure venting system is proposed to ensure that no measurable concentrations of TCE can enter the proposed businesses or the condominiums. The parking structure exhaust system will need to be in constant operation in order to prevent dangerous levels of carbon monoxide from accumulating in the building. Because the groundwater and direct contact pathways have already been addressed and significant contaminant source removed, this case could close under NR 726. The closure letter would require the operation and maintenance of the vapor barrier, passive venting and continuous operation of the parking exhaust system.

Example No. 3 – CVOC Groundwater Plume with Off-site Migration

An industry discovers a release from one of their underground TCE tanks. The subsequent investigation determines that a plume of contaminated groundwater extends under an adjacent sub-division. While the homes are on municipal water, the concentrations in groundwater are high enough that the vapor intrusion pathway needs to be evaluated. Initial soil gas sampling reveals relatively high levels of contaminants in the unsaturated zone near several of the homes in question, levels that may result in indoor air concentrations exceeding the VAL for TCE. The homes considered to be most at risk are targeted for follow-up sub-slab and indoor air sampling in order to determine whether a human health risk may exist. The remedy for this site includes soil removal from the source area along with the installation of an active groundwater treatment and soil vapor extraction (SVE) system. The remedy is intended to address control of the groundwater plume and to reduce vapor concentrations in the unsaturated zone.

- Scenario A – As long as the groundwater treatment / SVE system needs to operate to control plume expansion, closure of the site is not possible. If sub-slab screening levels

[19] Developers are urged to install vapor barriers with passive or active venting if volatile chemicals remain in soil or groundwater on property being redeveloped.

are exceeded at any of the nearby homes, indoor air sampling should be conducted. If sub-slab vapor concentrations are exceed but VAL are not exceeded, either an on-going indoor air vapor monitoring program should be established or a vapor mitigation system should be installed in the affected homes in order to address the potential risk to human health. If indoor air concentrations exceed VAL, mitigation of the vapor pathway will be required. Indoor air sampling should also be conducted after the mitigation system has been installed to ensure that an unacceptable risk to human health does not exist. Provisions should be made for on-going operation and maintenance of the mitigation system as well as periodic indoor air monitoring.

- Scenario B – Information is provided to document that operation of the groundwater treatment / SVE system is no longer needed to ensure the plume is stable or receding. The effect of the remedial effort on the vapor pathway is evaluated and sub-slab and indoor air monitoring at homes where the vapor pathway was identified as a concern reveal concentrations below applicable screening and VAL. Remedial efforts have effectively addressed the vapor pathway in this scenario and operation of the vapor mitigation system is no longer necessary. If all other requirements of NR 726 are met, the site qualifies for closure.

- Scenario C – The groundwater plume is determined to be stable or receding and the groundwater treatment / SVE system is shut down. TCE does not exceed the indoor air VAL, but sub-slab vapor sampling reveals that measured concentrations at several homes are greater than the screening level, requiring continued operation of the mitigation system. Operation of the groundwater treatment/SVE system should be continued or other remedial action be considered in order to eliminate to the extent practical the off-site vapor migration pathway to the nearby homes. Closure under NR 726 is not appropriate at this time.

- Scenario D – The groundwater plume is believed to be stable or receding without operation of the groundwater treatment / SVE system, but sub-slab vapor concentrations exceed screening levels for 2 homes that were previously unaffected. In addition to installation and operation of mitigation systems at the homes, additional remedial actions need to be evaluated including continued operation of the groundwater treatment / SVE system or other remedial action. Closure under NR 726 is not appropriate at this time.

<u>Example No. 4 – CVOC Contamination at an Operating Business with Later Redevelopment</u>
An existing dry cleaner recently completed a site investigation to define the degree and extent from a release of PCE at their current place of business. The investigation confirmed relatively high levels of soil contamination with the highest concentrations directly under the building. Due to the presence of low permeability soils (primarily silt and clay) groundwater impacts have been minor and monitoring has determined that the contaminant plume is not expanding. Action to address sub-slab soils may be necessary given the high soil matrix concentrations. After appropriate source control measures have been taken, there is not a direct contact issue at this site due to the presence of the building. The remaining issue is the potential for vapor intrusion into nearby structures and the dry cleaner building if building use changes in the future.

- Scenario A – The dry cleaner plans to continue operation at the site, which includes the use of PCE in the dry cleaning machine, and requests closure. The soil direct contact and groundwater pathways have already been addressed in accordance with NR 726. While it would be difficult to determine what affect vapor intrusion is having on the overall concentrations of PCE in the building because of on-going dry cleaning operations, sub-slab sampling should be conducted to evaluate whether vapor intrusion is a potential pathway of concern. In this case the indoor air quality standards that apply within the building are set by OSHA and are not exceeded.

  If the sub-slab vapor sampling indicates that vapor intrusion could be a potential problem if commercial indoor air exposure criteria were applied rather than OSHA indoor standards, consideration should be given to installing and operating a sub-slab vapor mitigation system to control lateral vapor movement away from the dry cleaner and thereby limit migration into nearby buildings. The current and future building owners would be responsible for on-going maintenance and operation of the mitigation system. If building use changes in the future and dry cleaning no longer occurs in the building, indoor air sampling will be necessary to assess vapor concentrations in the building. If a mitigation system has previously been installed, the indoor air sampling will determine the effectiveness of the mitigation system in controlling vapor intrusion into the building. In addition, the closure letter will require that the Department be notified of the air sampling results and the proposed land use change.

- Scenario B – At some point after the dry cleaner in Scenario A receives case closure, the owner vacates the building and a developer plans to remodel the space and rent it to several individuals interested in opening up a bookstore. Because OSHA rules no longer apply, an evaluation of the vapor pathway, using the appropriate indoor air exposure conditions, needs to be undertaken. If a vapor mitigation system is in operation, indoor air samples should be collected to determine whether there is a risk to human health. If indoor air concentrations are below VAL and the mitigation system is operational, no further action regarding the vapor pathway is needed. If a mitigation system was not previously installed or if VAL is exceeded, assessment of sub-slab and indoor air vapor will be necessary to determine the need for additional actions. If a health risk exists at the site, the Department will reopen the site in accordance with NR 726.09.

- Scenario C – After site closure, the vacated building undergoes redevelopment. A vapor mitigation system was not installed previously. It will be necessary to assess the vapor intrusion pathway, including testing sub-slab vapor and, perhaps, indoor air. If sub-slab vapor concentrations exceed screening levels, a remediation plan should be developed. If the building will be occupied prior to completion of the remedy, a mitigation system should be installed to address the potential human health risk. Verification indoor air samples will be necessary to determine that a human health risk does not exist. In this scenario, the Department would reopen and oversee the case until the contaminant pathway is addressed.

- Scenario D – After closure is issued under Scenario A, a developer purchases the property from the dry cleaner. The preliminary plans include demolition of the building

and construction of a new structure. The closure requires that the new property owner be notified of their responsibility to investigate and clean up subsurface contamination after building removal. In addition, the closure letter requires evaluation of the vapor intrusion pathway, including assessing additional source control actions and mitigation of the vapor pathway that may be necessary for the new building. The Department must be notified if contamination is found during the subsequent investigation. At the time of the future investigation, the new owner should contact the Department regarding the proposed development, protection of the various environmental pathways, and the need for additional source control.

Example No. 5 – Petroleum Release with Free-product and Off-site Migration of Groundwater

An underground tank leaks at a service station releasing gasoline into fractured bedrock. The free product gasoline at the water table is the source of a shallow groundwater plume that extends more than a city block downgradient of the service station. Beside the gas station is a church and half a block from the gas station, the local bank has a basement with two sumps to keep shallow groundwater from entering the building.

- Scenario A. Bank employees begin to complain of symptoms of burning eyes and an unusual odor in the basement. A consultant evaluates the building and determines there is not an explosion hazard. Water samples collected from the sumps are analyzed and show that benzene concentrations exceed 500 ppb. Results of indoor air sampling show benzene concentrations exceed the industrial/commercial VAL. Due to the proximity of the groundwater to the basement foundation, a sub-slab depressurization system cannot be installed. The vapors appear to be emanating from the sumps; therefore the sumps are both sealed and vented to the outdoors. Subsequent indoor air sampling confirms that benzene concentrations have fallen below the appropriate VAL. A maintenance plan should be developed to ensure that the sump seals are periodically inspected and the vapor vents are functional.

  Additional investigation of other buildings overlying the groundwater plume footprint reveals that the buildings are all slab on grade construction and that the presence of oxygenated, unsaturated soil between the plume and the buildings protect the buildings from petroleum vapors emanating off the plume. The remedial action occurring at the gas station will continue until the contaminants no longer pose a threat to human health or the environment.

- Scenario B. The church building abuts the gas station property and is located near the extent of free product but upgradient of the groundwater plume. The consultant assesses the possible vapor pathway to the church by conducting a survey of soil oxygen levels and soil benzene vapors between the church and the free product zone. Soil vapor samples are collected over depth intervals that assess the oxygen and vapor concentrations at least 5 feet below the church foundation and extend to approximately 2 feet below the ground surface. The survey shows that soil oxygen levels exceed 5% and benzene concentrations are near non-detect levels in the soil gas. The vapor pathway is not a risk to the church.

- Scenario C. The same circumstances as Scenario B, but the oxygen levels in the soil are near zero and the benzene levels indicate that vapor intrusion may present a risk to the church. Sub-slab vapor samples should be collected from below the church building. If sub-slab vapors exceed screening levels, mitigation should be implemented. If a SSD system is selected, it must be intrinsically safe to avoid an explosion risk. Closure can not occur at the gas station until the contaminants no longer pose a risk to human health or the environment.

Please contact Terry Evanson at Theresa.Evanson@wisconsin.gov or at 608-266-0941 if you have questions about this guidance.

State of Wisconsin

CORRESPONDENCE/MEMORANDUM

DATE: May 19, 2010

TO: RR Staff Statewide

FROM: Terry Evanson – RR/5

SUBJECT: Vapor Intrusion Action Levels and Screening Levels

The Remediation and Redevelopment (RR) Program works closely with the Division of Public Health (DPH) regarding vapor intrusion issues. The purpose of this memo is to document two important decisions made by the RR Management Team in cooperation with DPH.

Both agencies have agreed to use an excess life-time increased cancer risk of 1.0×10^{-5} or higher, and for non-carcinogens, a hazard index of 1.0, as a threshold for determining if a vapor action level for indoor air has been reached or exceeded. This risk level is in the middle of the acceptable inhalation risk range utilized by U.S. EPA and is high enough to exceed the background indoor air concentrations for most volatile compounds of concern.

In addition, the agencies have agreed that vapor screening levels (i.e., samples used to estimate indoor air from concentrations of vapors measured in sub-slab, soil gas, etc.) will be determined using the vapor action level divided by the appropriate attenuation factor developed by U.S. EPA. The attenuation factors currently found in EPA's guidance are:

- 0.1 sub-slab to indoor air
- 0.01deep soil gas to indoor air
- 0.001groundwater to indoor air (where vapor concentrations are calculated from partitioning across the water table using Henry's Law)

If U.S. EPA modifies the existing attenuation factors, the RR Program and DPH will adjust the levels accordingly.

The current drafts of the NR 700 rule series have been modified to be consistent with the criteria set out in this memo. If anyone has questions or needs further clarification, please do not hesitate to contact me at 608-266-0941.

cc: Henry Nehls-Lowe – Division of Public Health

APPROVED:

Mark F. Giesfeldt, P.E., Director
Bureau for Remediation & Redevelopment

Charles J. Warzecha, Director
Bureau of Environmental & Occupational Health

Evaluating the Vapor Intrusion Pathway